

Report No. CG-D-20-96, III

**Research Methods to Develop Measures of Effectiveness
of the United States Coast Guard's
Vessel Inspection and Boarding Program**

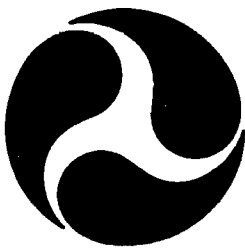
**DECISION SUPPORT FOR UTILIZING
MEASURES OF EFFECTIVENESS - VOLUME III**

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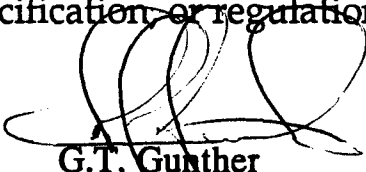
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Technical Report Documentation Page

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16. Abstract This report describes a methodology for determining the effectiveness of the U.S. Coast Guard Marine Inspection and Boarding Program for deep draft vessels. Measures of Effectiveness (MOEs) were developed at the overall program-wide, major activity, and sub-activity levels. Econometric analysis was performed on the relationship between the number of personnel and pollution casualties and the resource hours expended by the Inspection and Boarding programs. The estimates provide MOEs by 1) quantifying the decrease in expected number of casualties, and 2) quantifying the increase in the duration in days to a casualty that results from an increase in resource hours. A second methodology called Risk Based Ranking (RBR) was used to enumerate the contribution of factors targeted by sub-activities as being key contributors to the occurrence of casualties. For U.S. vessels the results indicate that resources expended are effective in reducing expected number of deaths, injuries, and pollution incidents. For foreign vessels the results are not robust and do not allow clear inferences. The RBR showed that the dominant contributors to maritime risk are linked to Drills/Human Factors, Steering/Navigation, and Cargo/Pollution Control sub-activity intervention strategies. The order of these factors varies by vessel service and country of registry. A prototype decision support system was developed that displays the econometric models graphically. This report is issued in four separate volumes: Volume I - Executive Summary; Volume II - Main Report; Volume III - Decision Support for Utilizing Measures of Effectiveness; Volume IV - Appendices.					
17. Key Words Econometric Analysis Risk Based Ranking Measures of Effectiveness Poisson Models Duration Models Decision Support System Marine Safety Boardings Marine Safety Inspections				18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161	
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METRIC CONVERSION FACTORS

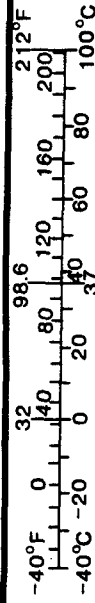
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	* 2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (WEIGHT)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft ³	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (EXACT)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10,000 m ²)	2.5	acres	
MASS (WEIGHT)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
m ³	cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (EXACT)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



INTRODUCTION

The purpose of this report, Volume 3, is to provide a guide to using the prototype decision support system (DSS) included with this report. The DSS graphically displays the econometric results developed in the main report, Research Methods to Develop Measures of Effectiveness of the United States Coast Guard's Vessel Inspection and Boarding Program, Main Report - Volume 2¹. This prototype displays results of three of the many statistical models that were created.

Some of the material in the introduction is taken from the main report in order to provide background to the user of this guide. The user is referred to the main report for complete descriptions of the models.

A DSS is an interactive, flexible, and adaptable computer-based information system, designed to support decision making where human judgment and experience are required. It provides a user friendly interface to display data and is controlled by the decision maker allowing for incorporation of expert knowledge into the problem solving and decision making process. Tasks such as assessing the effectiveness of USCG activities require both expert judgment and data analysis. The DSS must therefore include flexible models and a modeling capability.

The model's user interface was developed using Visual Basic in Microsoft Excel 5.0. The model allows users to graphically view the results of the econometric models developed in the main report. The user can take advantage of the extensive graphical and numerical capabilities of EXCEL to customize and analyze the output of the models. The output of the models and format of the graphs can easily be manipulated to best meet the needs of the user². Excel files can be converted to Lotus applications, and Excel runs on both Windows and Macintosh platforms.

The following material is a step-by-step guide to using the prototype DSS. Three models were selected to demonstrate the use of the DSS as follows:

(1) Poisson Model 4.5.2 (model 5) is listed in Table 4.5.2 on page 4-42 of the main report. This model is a level I measure of effectiveness for resource hours spent inspecting machinery spaces and equipment on U.S. flag freight and tank vessels. It is a Poisson model which predicts

¹Research Methods to Develop Measures of Effectiveness of the United States Coast Guard's Vessel Inspection and Boarding Program, Volume 2 - Main Report, Sandia National Laboratories: 1995

² The user is assumed to know how to use Microsoft Excel 5.0 to take advantage of these capabilities.

the yearly number of pollution occurrences in relationship to the number of machine inspection hours performed on those vessels. Further information is available in section (ii) Pollution Casualties, on page 4-26 of the main report. The mathematical formulation for the model is:

$$y = \frac{Num_Ships}{3} e^{C + DF \cdot \beta_{Mach_F} \cdot HRS + DT \cdot \beta_{Mach_T} \cdot HRS + \beta_{AGE} \cdot AGE}$$

where

y is the number of pollution occurrences per year,

Num_Ships is the total number of ships of the type considered by the model,

C is the Beta constant,

DF & DT are boolean variables indicating the ship type considered by the model,

β_{AGE} is the beta estimate for Age of vessel, where AGE is the age of ship type,

β_{Mach_X} is the beta estimate for Machine Hours spent on ship type X , and

F & T correspond to Freighters and Tankers respectively.

(2) Duration Model 4.6.3 (model 4) is listed in Table 4.6.3 on page 4-48 of the main report. This model is a level II measure of effectiveness for the certificate of inspection (COI) activity and measures the duration in days from the last COI on a particular vessel to the closest pollution casualty if any for that vessel. Specifically it predicts the duration in days to a personnel casualty in relationship to the number of Hull Inspection hours performed on U.S. flag passenger vessels, freighters and tankers. Further information is available in section 4.4.3.1 on page 4-43 of the main report. The mathematical formulation for the model is:

$$y = \frac{Num_Ships}{3} e^{C + DP \cdot \beta_{Hull_P} \cdot HRS + DF \cdot \beta_{Hull_F} \cdot HRS + DT \cdot \beta_{Hull_T} \cdot HRS + \beta_{AGE} \cdot AGE}$$

where

y is the average duration, in days, to a casualty,

Num_Ships is the total number of ships of the type considered by the model,

C is the Beta constant,

DP , DF & DT are boolean variables indicating the ship type considered by the model,

β_{AGE} is the beta estimate for the vessel age,

β_{Mach_X} is the beta estimate for Machine Hours spent on ship type X , and

P , F & T correspond to Passenger Vessels, Freighters and Tankers respectively.

(3) Poisson Model 4.12.3 (model 5), is listed in Table 4.12.3 on page 4-68 of the main report. This model is a level III measure of effectiveness for resource hours spent on the level III

activities of Cargo/Pollution Handling/ Pollution control for U.S. flag passenger vessels, freighters and tankers. It predicts the yearly number of pollution occurrences in relationship to the number of resource hours spent on these level III activities. The mathematical formulation for the model is:

$$y = \frac{Num_Ships}{3} e^{C + DP \cdot \beta_{Mach_P} \cdot HRS + DF \cdot \beta_{Mach_F} \cdot HRS + DT \cdot \beta_{Mach_T} \cdot HRS + \beta_{AGE} \cdot AGE}$$

where

y is the number of pollution occurrences per year,

Num_Ships is the total number of ships of the type considered by the model,

C is the Beta constant,

DP, DF & DT are boolean variables indicating the ship type considered by the model,

β_{AGE} is the beta estimate for vessel age,


β_{Mach_X} is the beta estimate for Level III hours spent on ship type X, and

P, F & T correspond to Passenger Vessels, Freighters and Tankers respectively.

These models are representative of those developed in volume 2. As noted in the main report and the executive summary, the prototype DSS should be expanded by incorporating additional models. USCG Office of Marine Safety personnel should prioritize the models described in the report and implement them as time and resources permit. In addition, a "model management" interface should be developed. This interface would guide the user to the model most appropriate to the task being addressed by USCG program staff.

TUTORIAL

This tutorial is designed to provide guidance in using the models in the prototype DSS, explain how to use the features provided by the system, and to provide sample inferences which can be drawn from the graphs and charts. The DSS incorporates much on this information in on-line help screens. A more extensive discussion of the capabilities of the each model is given in the main report.

The features provided by the prototype DSS are similar for each of the models. However, the inferences that can be made depend upon the model and its anticipated use by the decision maker. Specific instructions, such as **ENTER**, which means hit the enter key, will be in **BOLD**. Screen displays of the actual DSS are used and button icons that are used to select options are indicated graphically such as the following RETURN button . Also, inferences which may be drawn from the displays will be written in *italics*. The resulting output from various commands is provided exactly as it should look on the computer screen.

OPEN the file: DSS.XLS

The EXCEL 5.0 workbook will open to the Main Menu sheet shown below.




USCG Office of Marine Inspection Decision Support System for Boarding and Inspection Processes




**Get Info About
Models**

Select Model

**Get Info About
Models**

The  button displays a list box that enables the user to select general on-line help about the DSS or about a particular model of interest.

Select Model

The  button displays a different list box that moves the user to the particular model of interest.


On-Line Help:

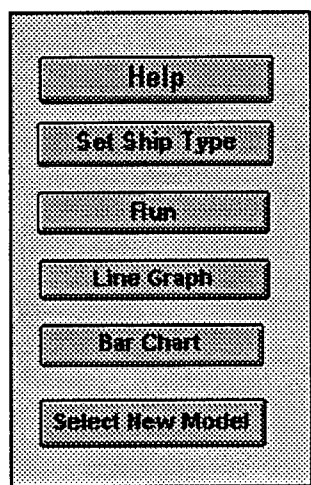
CLICK on: 

This will display a list box that allows the user to select information on the DSS in general or to select help on any of the models in the DSS.

PART 1: Poisson Model 4.5.2 (model 5)

DOUBLE CLICK on: Model 4.5.2 (model 5)


This will bring the user to a brief section describing this particular model and its referenced pages in the main report. Review this information then **CLICK on**  to use the model. You will be moved to the following main sheet for model 4.5.2 (model 5) similar to the one shown below.

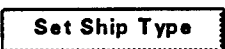


A vertical stack of six rectangular buttons with a shaded background. The buttons are labeled: Help, Set Ship Type, Run, Line Graph, Bar Chart, and Select New Model.

Model Input	
Ship Type (F, T)	f
Machine Hours	0.498
Age (yrs)	24.0
Number of Vessels	503.0

Model Output	
Predicted pollution occurrences	31.07
95% confidence +/-	11.15
Avg yearly number of pollution occurrences	31.07

CLICK on Help: to get general information on using this model. When completed, **CLICK on**  to return to the model's main menu sheet.

CLICK on: . This displays a dialog box that enables you to choose the type of vessel.

TYPE in: F and **CLICK** 

This signifies that you will be using only the data for Freight vessels in this example. The model will automatically fill in the necessary values in the Model Input section.

CLICK on: The **Run** button

This will recall certain constants particular to this model and perform the necessary calculations to draw the graphical output for the model.

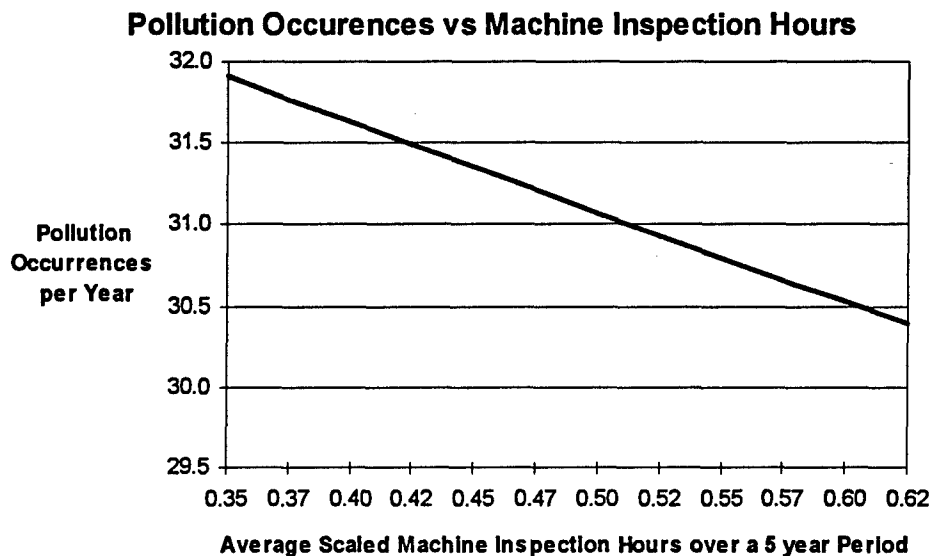
NOTE the outcome in the Model Output section:

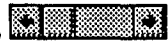
Predicted pollution occurrences	31.07
95% confidence +/-	11.15
Avg yearly number of pollution occurrences	31.07

Click on **Line Graph**:

This brings the user to the line graph on the model sheet, the Predicted Number of Pollution Occurrences vs Machine Inspection Hours graph. Notice that Machine Inspection hours are scaled by gross tonnage of the vessel and aggregated over a five year period.

Notice that as you increase the amount of scaled machine inspection hours the number of pollution occurrences decrease.



You can rescale the Y-axis of the graph using the sliding bars  to the right of the graph. After selecting values for Y-max and Y-min,

CLICK on: The **Scale** button

This will rescale the graph using the values for Y-max and Y-min that you have selected. If you accidentally choose an range that makes the line of the graph disappear entirely, Click

on the **Return** button and then the **Line Graph** button in order to return to the default settings.

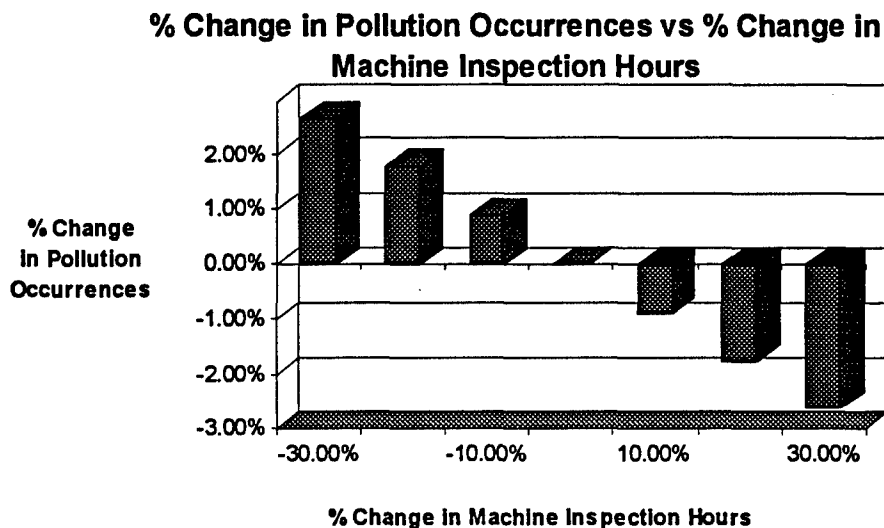
Note that while average machine inspection hours scaled by the gross tonnage of the vessel is not an intuitive measure for the decision maker, the fact that the number of pollution occurrences decreases with increasing inspection hours indicates that the hours spent on these activities are associated with reducing the number of pollution occurrences. The Bar Chart can give additional insight in a more intuitive manner.

CLICK on: The **Return** button

This brings the user back to the main menu.

CLICK on: The **Bar Chart** button

This brings the user to the bar chart on the model sheet, % Change in Pollution Occurrences vs % Change in Machine Inspection Hours. The numbers at the bottom indicate the percentage change from the average number of inspection hours. The Y-axis indicates the corresponding expected percentage change in the number of pollution occurrences.



We can see that a 20% increase in scaled machine hours is associated with an approximate 1.75% decrease in the number of pollution occurrences.


CLICK on: The **Return** button

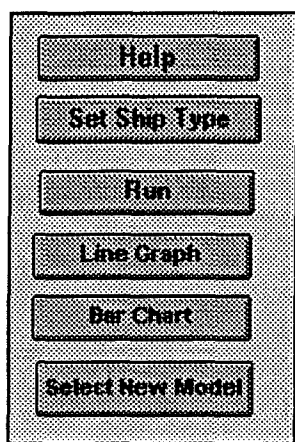
This brings the user back to the main menu. To select a new model Click on **Select New Model**.

PART 2: Duration Model 4.6.3 (model 4)

Click on: 

DOUBLE CLICK on: Model 4.6.3 (model 4)

This will bring the user to a brief section describing this particular model and it's referenced pages in the main report. Review this information then **CLICK on**  to use the model. You will be moved to the main sheet for model 4.6.3 (model 4) similar to the one shown below.





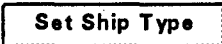
Model Input

Ship Type (F, P, T)	f
Hull Hours	0.048
Age (yrs)	24.0
Number of Vessels	332.0

Model Output

Predicted Duration to Casualty	793.72
95% confidence interval +/-	56.35
Average Yearly Scaled Hull inspection Hours	3.19
Average Duration to Casualty (days)	793.72

CLICK on : to get general information on using this model. When completed, **CLICK on**  to return to the model's main menu sheet.

CLICK on: . This displays a dialog box that enables you to choose the type of vessel.

TYPE in: F and **CLICK** .

This signifies that we will be using only the data for Freight vessels in this example. The model will automatically fill in the necessary values in the Model Input section.

CLICK on: The  button

This will recall certain constants particular to this model and perform the necessary calculations to draw the graphical output for the model.

WAIT

NOTE the outcome in the Model Output section:

Predicted Duration to Casualty

95% confidence interval +/-

Average Yearly Scaled Hull inspection Hours

793.72

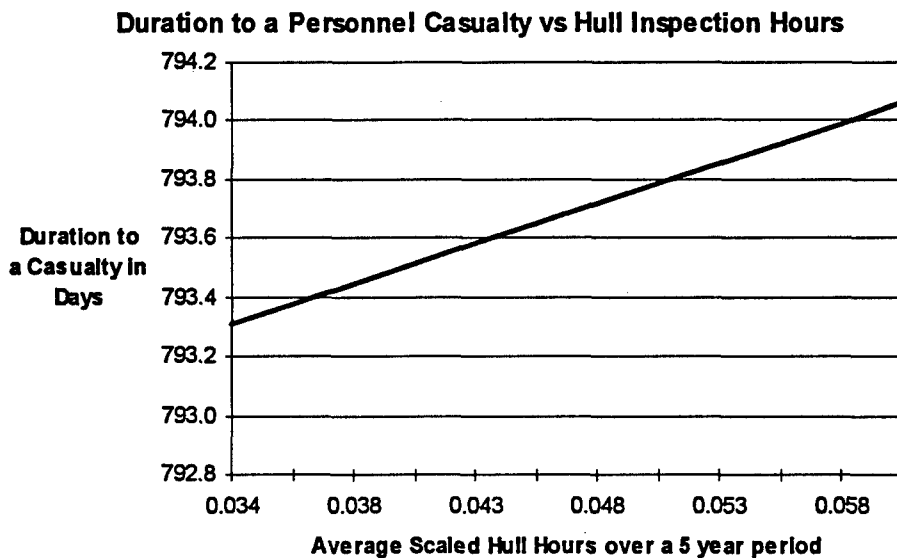
56.35


3.19

Click on **Line Graph**:

This brings the user to the line graph on the model sheet, the Duration to a Personnel Casualty vs. Hull Inspection Hours graph. Notice that Hull Inspection hours are scaled by gross tonnage of the vessel and aggregated over a five year period.

Notice that as you increase the amount of scaled hull inspection hours, the duration in days to a personnel casualty increases only slightly.



You can rescale the Y-axis of the graph using the sliding bars  to the right of the graph. After selecting values for Y-max and Y-min,

CLICK on: The **Scale** button

This will rescale the graph using the values for Y-max and Y-min that you have selected. If you accidentally choose an range that makes the line of the graph disappear entirely, Click on the **Return** button and then the **Line Graph** button in order to return to the default settings.

Note that while average hull inspection hours scaled by the gross tonnage of the vessel is not an intuitive measure for the decision maker, the fact that the duration in days from inspection to a pollution occurrence increases with increasing hull inspection hours

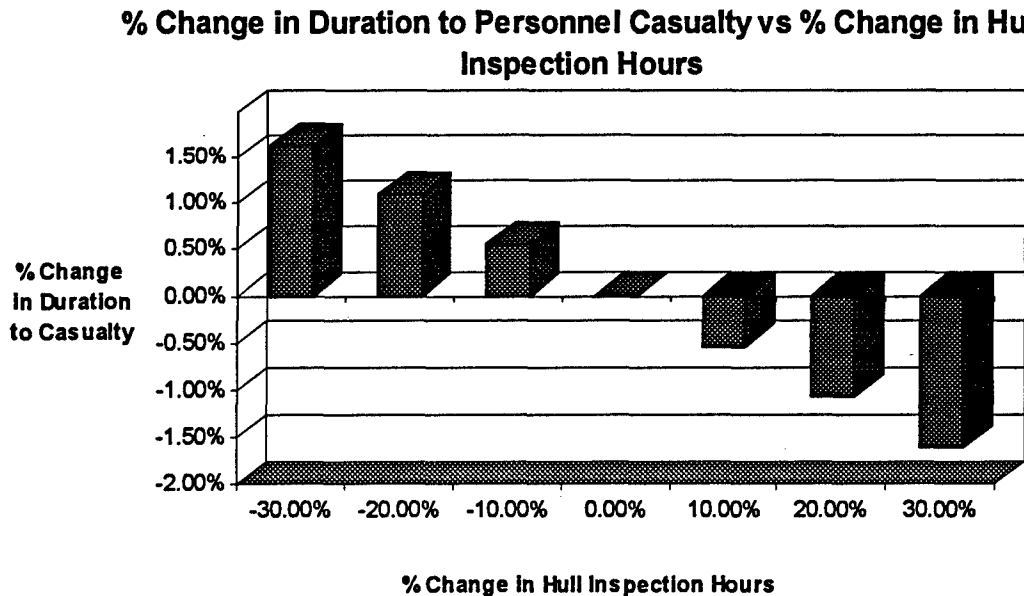
indicates that the hours spent on these activities are effective. The Bar Chart can give additional insight in a more intuitive manner.

CLICK on: The **Return** button

This brings the user back to the main menu.

CLICK on: The **Bar Chart** button

This brings the user to the bar chart % Change in Duration to Personnel Casualty vs % Change in Hull Inspection Hours. The numbers at the bottom indicate the percentage change from the average number of inspection hours. The Y-axis indicates the corresponding expected percentage change in the number of days to a personnel casualty.



Let's assume that it was necessary to cut expenditures, and to do that it was decided that hull inspection hours would be cut by 20%. That scenario would lead to an 1.3% decrease in the duration to a casualty. Using the average duration to casualty of 703.192 days, the model predicts that the duration to casualty will decrease, on average, by 9.14 days.

CLICK on: The **Return** button

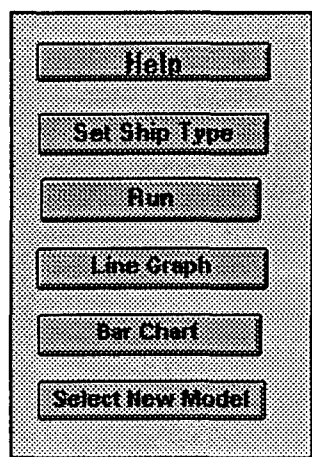
This brings the user back to the main menu. To select a new model Click on **Select New Model**

PART 3: Poisson Model 4.12.3 (model 5)

Click on:

DOUBLE CLICK on: Model 4.12.3 (model 5)

This will bring the user to a brief section describing this particular model and it's referenced pages in the main report. Review this information then **CLICK** on to use the model. You will be moved to the following main sheet for model 4.12.3 (model 5) similar to the one shown below.



Model Input	
Ship Type (F, P, T)	p
Scaled Machine Hours	0.018
Age (yrs)	35.5
Number of Vessels	147.0

Model Output	
Predicted pollution occurrences	6.53
95% confidence +/-	5.11
Average yearly pollution occurrences	6.53

CLICK on : to get general information on using this model. When completed, **CLICK** on to return to the model's main menu sheet.

CLICK on: . This displays a dialog box that enables you to choose the type of vessel.

TYPE in: P and **CLICK** .

This signifies that we will be using only the data for Passenger vessels in this example. The model will automatically fill in the necessary values in the Model Input section.

CLICK on: The button

This will recall certain constants particular to this model and perform the necessary calculations to draw the graphical output for the model.

WAIT

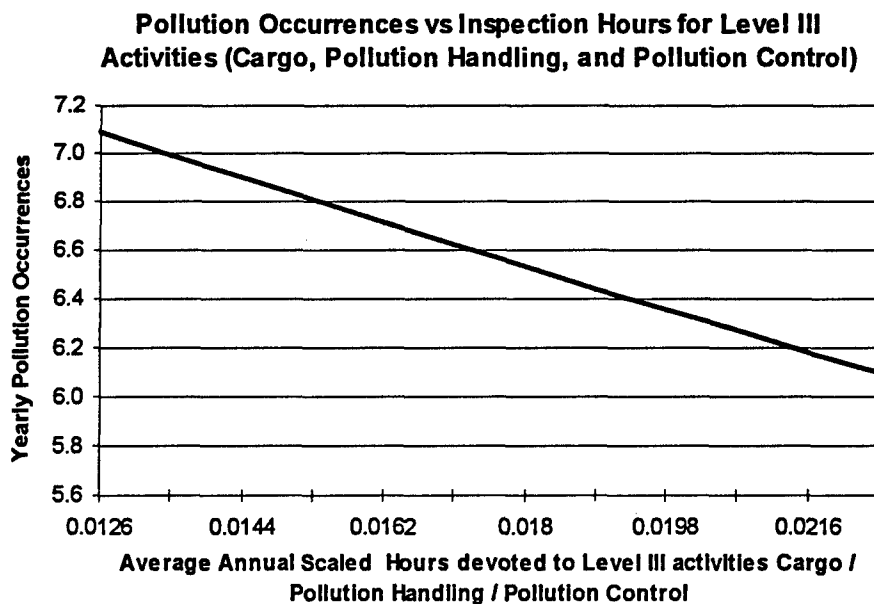
NOTE the outcome in the Model Output section:


Predicted pollution occurrences	6.53
95% confidence +/-	5.11
Average yearly pollution occurrences	6.53

Click on **Line Graph**:

This brings the user to the line graph on the model sheet, the Pollution Occurrences vs Inspection Hours for Level III Activities (Cargo, Pollution Handling, and Pollution Control) graph. Notice that the level III inspection hours are scaled by gross tonnage of the vessel and aggregated over a five year period.

Notice that as you increase the amount of inspection hours dedicated to these Level III MOE activities, the number of personnel casualty decreases.



You can rescale the Y-axis of the graph using the sliding bars  to the right of the graph. After selecting values for Y-max and Y-min,

CLICK on: The **Scale** button

This will rescale the graph using the values for Y-max and Y-min that you have selected. If you accidentally choose an range that makes the line of the graph disappear entirely, **Click on the** **Return** button and then the **Line Graph** button in order to return to the default settings.

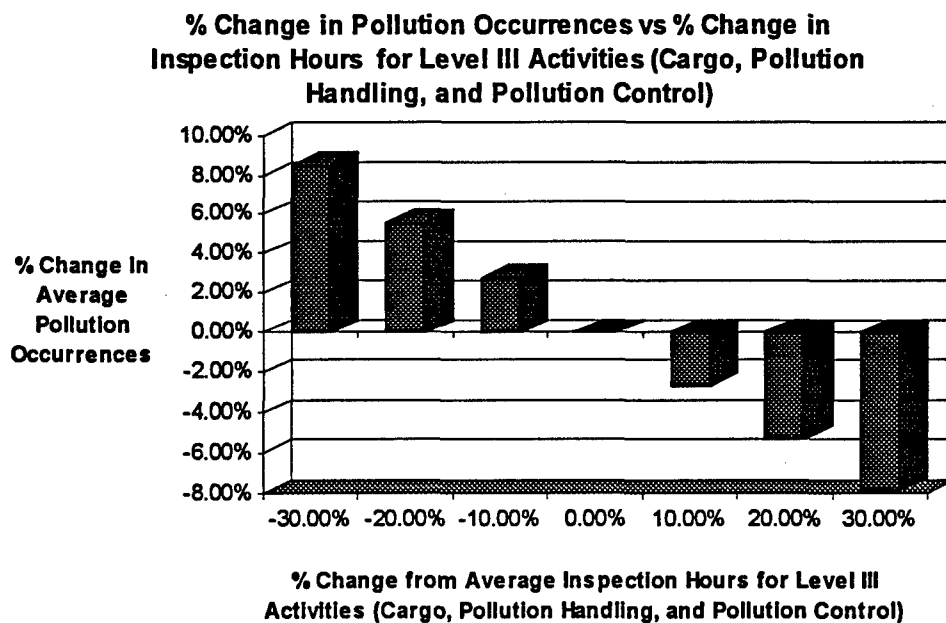
Note that while average inspection hours scaled by the gross tonnage of the vessel is not an intuitive measure for the decision maker, the fact that the number of pollution occurrence decreases with increasing Level III inspection hours indicates that the hours spent on these activities are effective. The Bar Chart can give additional insight in a more intuitive manner.

CLICK on: The **Return** button

This brings the user back to the main menu.

CLICK on: The **Bar Chart** button

This brings the user to the bar chart % Change in Duration to Personnel Casualty vs % Change in Hull Inspection Hours. The numbers at the bottom indicate the percentage change from the average number of inspection hours. The Y-axis indicates the corresponding expected percentage change in the number of days to a personnel casualty.



*Notice, a 20% increase in scaled these Level III inspection hours yields a 5.5% decrease in pollution occurrences. Remember that this outcome is for Passenger Vessels only; to try another vessel type return to the main menu sheet by Clicking on **Return** to change the ship type and rerun the model.*

CLICK on: The **Return** button

This brings the user back to the main menu. To select a new model Click on **Select New Model**